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# THESIS

ANALYSIS OF RESUPPLY OPTIONS
FOR AN ARMOR BATTALION

by

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March 1989

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# ABSTRACT

Forward area resupply of combat maneuver units is analyzed in this thesis by using the Janus(TRASANA)(T) high resolution combat model. The goal of this thesis is to analyze two different resupply vehicles and various doctrinal concepts for the deployment of these vehicles. Combat between a United States Army battalion task force and two Soviet tank regiments generates a need for the U.S. force to resupply. Using various doctrines the resupply vehicles will attempt to provide logistic support to the U.S. forces.

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# I.  INTRODUCTION

## A.  BACKGROUND

Since World War II, the United States Army has been fielding combat vehicles with greater mobility, firepower, and survivability. The tactics and doctrine of the Army have become more offensively oriented to improve the utilization of these new combat systems' capabilities.  The Warsaw Pact forces have been making similar improvements in their equipment and doctrine.  While these advances have been made in the areas of combat vehicles, the logistic vehicles tasked to provide the logistic support for the combat vehicles and the AirLand Battle doctrine have not changed since the 1940s. The modern Army is still supported by wheeled, soft-skinned vehicles similar to the vehicles which supported the Army in World War II.   These logistic vehicles are lacking the mobility of modern fighting vehicles,  and do not provide protection to the crew and cargo from artillery and small arms fire.  The United States Army needs improved logistic vehicles if it is to be successful on the modern lethal battlefield. Based upon this concept, this thesis will analyze two different logistic vehicles and five doctrines for support of the modern Army.

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## B. PURPOSE AND GOAL

The purpose of this thesis is to analyze the logistic requirements of a United States Army armor battalion and recommend a logistic fleet and doctrine which can provide the logistic support required on the modern battle field. The Janus(T) combat model will be used to provide the combat scenario which will generate the logistic requirements for the resupply fleet to replenish.

The Janus(T) combat model is a high resolution combat model which can simulate the interaction of individual combat systems on the battlefield. Janus(T) is an approved and widely used combat model for combat simulations by the U.S. Army. It was chosen for this thesis because of its ease of use, terrain resolution, and its ability to be used as an analysis tool.

Specifically, the goal of this thesis is to analyze various resupply fleets and the doctrine for resupplying a combat battalion in a defensive scenario.

## C. METHODOLOGY

To build a scenario, an area in the Federal Republic of Germany near the Fulda Gap was chosen. This area was selected because it resembles the terrain on which the Army will fight in a European combat scenario. A Soviet force (Red) will attack a defending U.S. Army force (Blue). The resulting combat will generate the need for the Blue force to

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resupply ammunition and fuel. Three different types of ammunition, (120mm tank main gun, TOW missiles, and 25mm chain gun) and one type of fuel (diesel) will be resupplied by the Blue force's organic resupply fleet. This resupply fleet will be allowed to be attrited by Red artillery fire.

Based upon different configurations of the resupply fleet and different doctrines concerning the deployment of these fleets, various results will be achieved by the fleet in its attempt to resupply the Blue force. The result of the resupply effort to replace expended ammunition and fuel will be analyzed along with the outcome of the combat scenario to evaluate the different fleets and the various doctrines for their use.

# II. MODEL DEVELOPMENT

## A. SCENARIO

### 1. Force Structure

The Blue defending unit is a battalion task force consisting of two M1A1 Abrams Main Battle Tank (MBT) equipped Armor companies, two M2 Bradley Infantry Fighting Vehicle (IFV) equipped Infantry companies, and one M3 Cavalry Fighting Vehicle (CFV) equipped Scout platoon. The Blue forces are defending from prepared fighting positions. The Red attacking force consists of two tank regiments from a Soviet tank division equipped with the Future Soviet Tank-2 (FST-2), and BMP-2. The Red forces have the organic regimental artillery along with the higher-echelon artillery systems normally available at the regimental level. The Soviet force organization, equipment, and tactics were obtained from U.S. Army field manuals. [Refs. 1 and 2] Initial force structure of the Blue force is shown in Table 1, and the initial force structure of the Red force is shown in Table 2.

### 2. Terrain

The battle area in this scenario was chosen because it is the typical terrain on which the U.S. Army could be expected to fight in Europe. The Fulda Gap is an historical avenue of approach into Germany. It is one of the major

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TABLE 1

INITIAL BLUE COMBAT EQUIPMENT

| Weapon Class | Type | Weapon | Number |
|---|---|---|---|
| Direct Fire Weapons | MBT | M1A1 | 30 |
| | IFV | M2 | 26 |
| | CFV | M3 | 6 |
| Indirect Fire Weapons | Mortar | 4.2 in | 6 |
| | Howitzer | 155 mm | 24 |

TABLE 2

INITIAL RED EQUIPMENT

| Weapon Class | Type | Weapon | Number |
|---|---|---|---|
| Direct-Fire Weapons | MBT | FST-2 | 180 |
| | IFV | BMP-2 | 60 |
| Organic Indirect-Fire Weapons | Mortar | 82 mm | 12 |
| | Howitzer | 122 mm SP | 36 |
| Higher-Echelon Indirect-Fire Weapons | Howitzer | 122 mm SP | 36 |
| | Howitzer | 152 mm SP | 18 |
| | MRL | BM-21 | 18 |
| Helicopters | ATK | Hind D | 8 |

avenues of approach that the Soviets are expected to use in an invasion of Europe. This area is characterized by gently rolling farmland with forested hillsides. The countryside is dispersed with small farming villages connected by secondary class roads. Numerous small streams and rivers do not pose significant obstacles to a mounted Red attack. A map of this terrain area with the Blue defensive battle positions and the Red avenues of attack is shown in Figure 1.

### 3. Combat Scenario

The combat scenario utilized in this thesis was designed to stress the forward area resupply capabilities of a defending Armor task force. The battle takes place several days into the war, and the Blue forces no longer have large enough ammunition supplies for full combat loads of ammunition. This assumption was made to force the combat units to resupply. Several trial runs of the scenario showed that the Blue forces, if given full basic loads of ammunition, could defeat the two Red regiments without a need for resupply.

The Blue force is defending from a battalion battle position with the four companies each fighting as a pure unit from a company battle position. Battalion scouts are screening in front of the battalion. Their mission is to detect the Red force and to deceive the Red force about the true battle positions of the Blue force.
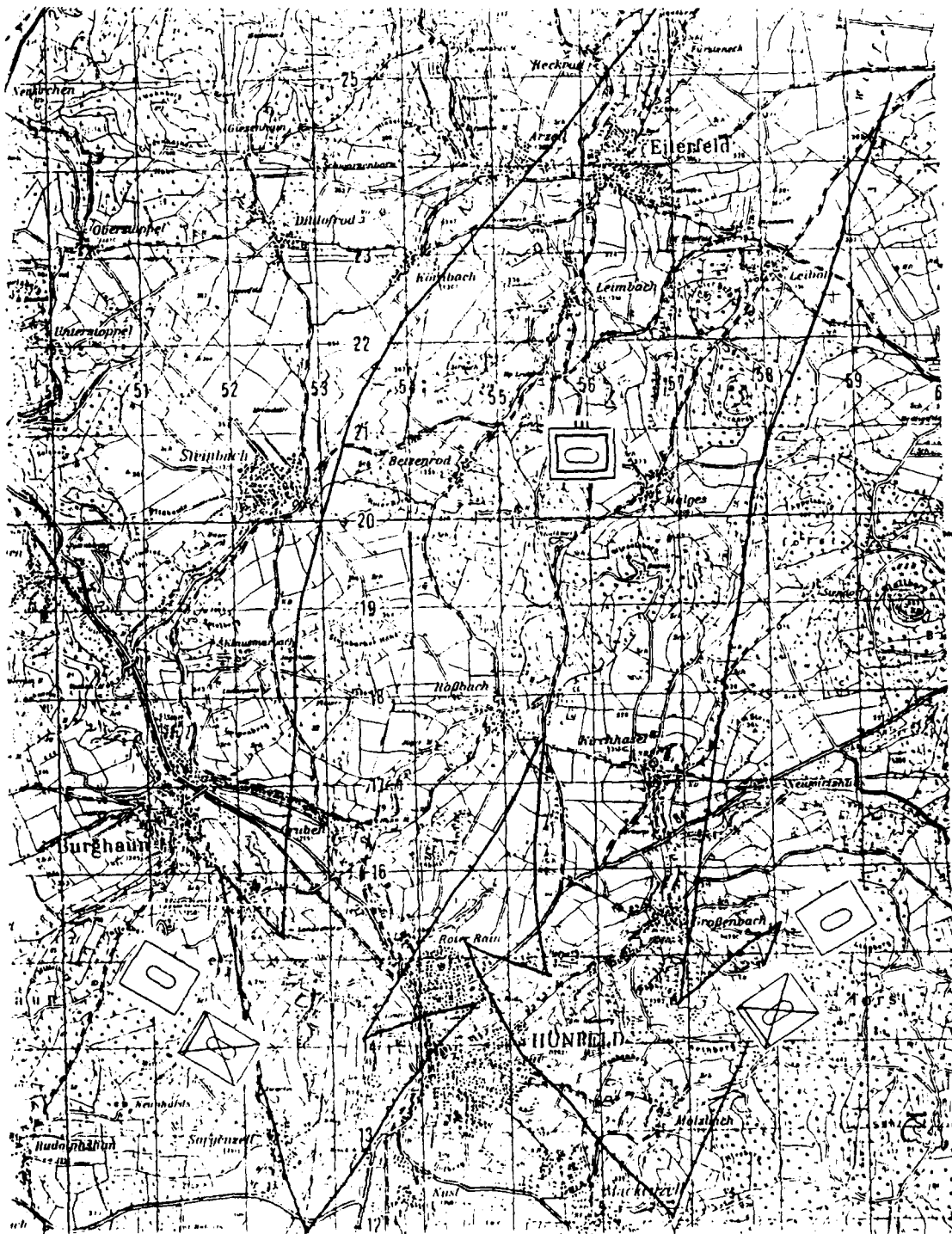
**Figure 1.** Map of Scenario Area

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The attacking Red force is composed of two tank regiments from a Soviet tank division. Figure 2 shows the initial deployment of the leading Red regiment. There are three tank battalions in each of the regiments, each consisting of three tank companies and a reinforcing BMP company. Both regiments are attacking with two lead battalions abreast, and the third battalion is trailing behind the leading two. The second echelon regiment is trailing fifteen kilometers behind the leading regiment. All of the combat vehicles in the units are positioned to the norms of Soviet doctrine. Each combat vehicle has been assigned its own attack route which will keep it in formation with the other vehicles in the unit.

This combat scenario will be repeated for each of the resupply options. The actual ground combat will be held as constant as possible while the various resupply options are used to resupply the ammunition expended by the Blue force. For each of the resupply options the first 45 minutes of simulation will be held constant. This 45 minute period is the end of first regiment battle and the point from which the scenario continues for each of the resupply options. The first regiment will stop its advance, reorganize its remaining forces, and await the arrival of the second regiment. Upon arrival of the second regiment the Red force will continue its attack.

ZONE OF ATTACK

REGIMENTAL
FIRST ECHELON

REGIMENTAL
SECOND ECHELON

RAG

3-8 KM

Distances Approximate

10 KM

5 KM

3 KM
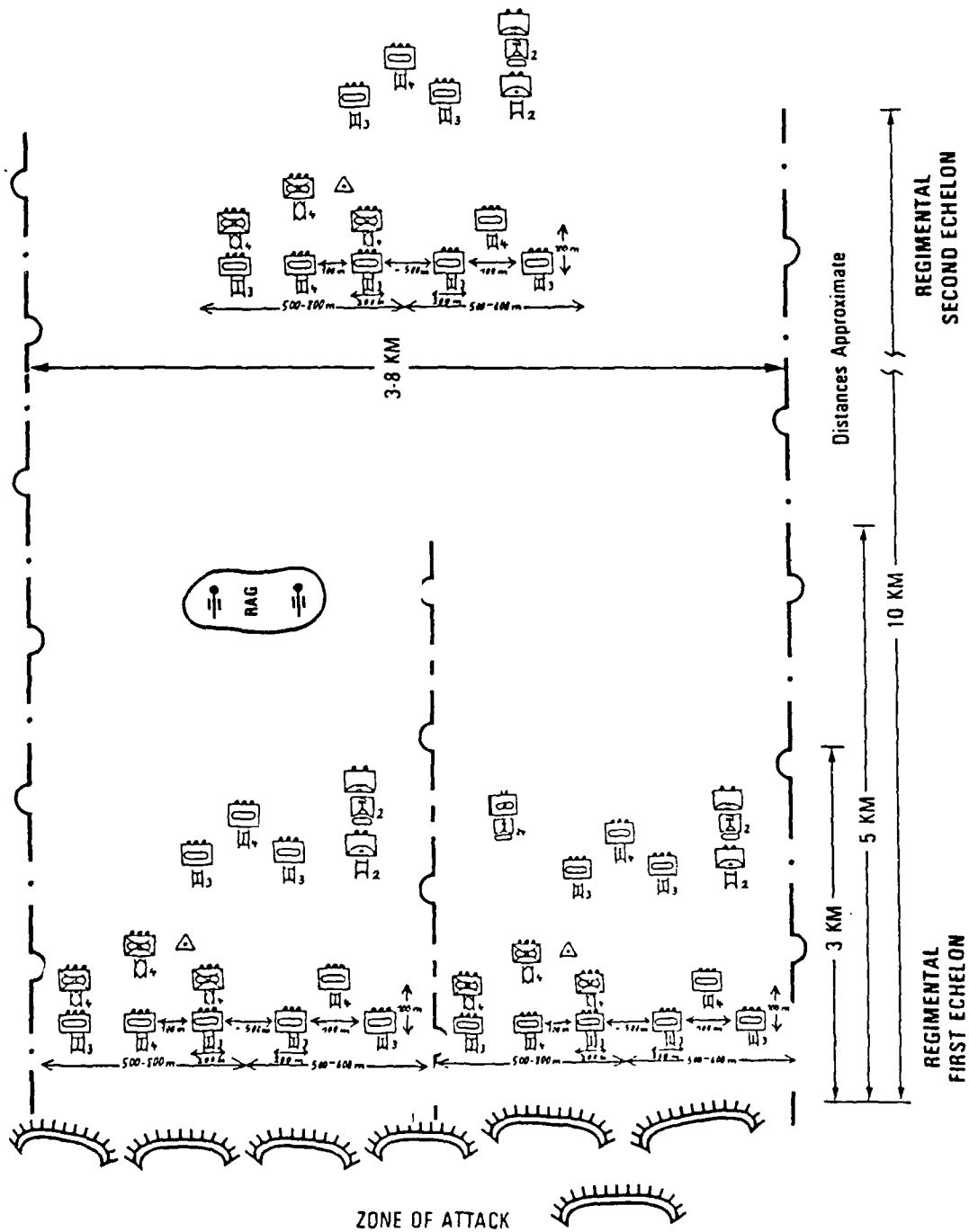
Figure 2. Soviet Formation

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## 4. Assumptions

The assumptions and description of the scenario are as follows:

- The probability of hit and kill for each direct fire weapon system is valid.

- All other operating characteristics for the combat systems are valid.

- Only a conventional warfare environment is considered in this thesis.

- Estimates of the fuel consumption rates for the Blue forces are valid.

- HEMTT resupply vehicles will replace the current fleet of 5-ton trucks and trailers used in Infantry battalions.

## B. MODEL PARAMETERS

### 1. Janus (T)

Janus(T) was developed primarily as an analysis tool to support Cost and Operational Effectiveness Analysis (COEA), tactics and doctrine analysis, and other Army studies. It was developed by the Army Training and Doctrine Analysis Command- -White Sands Missile Range (TRAC-WSMR). Individual combat systems are modeled in Janus(T). The system functions represented are moving, searching, detecting, and firing on the ground or in the air. Primary focus is on the combat systems that participate in maneuver and artillery operations on land. Terrain used in the model is represented in three dimensions and is user-selected. The Janus(T) combat model is very flexible. It allows for the different operating characteristics of combat systems to be easily changed. The

data base for the Janus(T) model is provided by the Army Material Systems Analysis Activity (AMSAA) and accepted throughout the U.S. Army. Janus(T) is easily configured to allow for the answering of "what if" questions. The operating characteristics of combat systems and the deployment of these systems are easily modified in Janus(T). [Ref. 3]

## 2. Direct Fire

The direct fire engagements in the simulation occur between the Blue and Red units with as little interference by the players as possible. This is done to keep the scenario constant so the combat outcome will be a function of the Blue resupply effort rather than a change in tactics by the player. Some player interaction is required to maintain realistic fields of view for the Blue vehicles after they return to position from being resupplied. Often after a Blue vehicle returns from the resupply point to its battle position its field of view is not oriented in the correct direction.

## 3. Indirect Fire

The number of Red artillery pieces played represents the artillery weapons present in two Regimental Artillery Groups (RAG) and supporting artillery pieces from the Divisional Artillery Group (DAG) that are available to the forward regiments. A battalion of 155mm self propelled (SP) artillery is played for the Blue forces. Normally a Blue combat battalion would only expect the artillery fires of one battery. It was assumed the Armor task force had priority

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of artillery fires and would receive the fire support of the entire artillery battalion.

4. **Combat Vehicle Capabilities**

   a. **Ammunition**

   The on-board capacities of ammunition for the Blue and Red forces are based upon design criteria for the Blue force and projected capabilities of the Red force. Usage rates by both forces depend on the initial input parameters and are a function of the combat between the forces. Only the major weapons on the combat vehicles are modeled in this thesis. This includes the 120mm main gun on the M1A1 and the TOW missiles and 25mm gun on the M2/M3. The on-board ammunition storage capability for the Blue forces is listed in Table 3.

TABLE 3

AMMUNITION STORAGE CAPABILITY

| VEHICLE | AMMUNITION | CAPACITY |
|---------|------------|----------|
| M1A1 | 120MM | 40 |
| M2 | 25MM | 900 |
| | TOW | 7 |
| M3 | 25MM | 1500 |
| | TOW | 12 |

It was found during test runs of the simulation that if the full basic loads of ammunition as listed in Table 3 were used, the resupply system would not be stressed. The

combat vehicles had sufficient on board ammunition to defeat both attacking regiments before expending their basic loads of ammunition. This situation caused it to be more efficient for the Blue force to not resupply than to replace expended ammunition. Greater numbers of Red forces were killed, and a larger number of Blue survived if no resupply was attempted. The reason is that once a Blue vehicle begins movement, it losses the protection of being in a defilade position and has a greater chance of being detected and killed by the Red force. Therefore, it was to the Blue force's advantage not to attempt resupply and fight using the remaining ammunition rather than suffer losses while attempting to resupply. This is an unrealistic scenario, as the surviving Blue force would be completely out of ammunition and unable to continue its defensive mission.

The amount of on-board ammunition available for each vehicle was reduced from the production storage capability listed in Table 3. This reduced load of ammunition represents the amount of ammunition which may be available due to limited supplies available after several days of combat. The reduced basic load for the Blue force vehicles is listed in Table 4.

TABLE 4

REDUCED BASIC LOAD

| VEHICLE | AMMUNITION | AMOUNT |
|---------|------------|--------|
| M1A1    | 120MM      | 20     |
| M2      | 25MM       | 900    |
|         | TOW        | 5      |
| M3      | 25MM       | 1500   |
|         | TOW        | 9      |

## b. Fuel

Before this thesis, the monitoring of the fuel usage by vehicles had not been modeled in Janus(T). The vehicles operated on an unlimited supply of fuel, and in the unrealistic environment of no fuel usage constraints. Vehicles can now be limited to the design capabilities of their fuel tanks. Usage rates of fuel depend upon and correspond to the vehicle's status as either stationary or moving. Different rates of fuel usage, input as model parameters, can be assigned to vehicles for computing fuel consumption. The Red force in this simulation was given a very low fuel usage rate eliminating the requirement for the resupply of fuel by the Red forces. Blue forces were assigned fuel usage rates obtained from the Armor School at Fort Knox, Kentucky. The usage rates for the Blue forces are in Table 5.

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TABLE 5

BLUE FORCE FUEL USAGE RATES

| VEHICLE | STATIONARY | MOVING |
|---------|------------|--------|
| M1A1 | 11.0 GAL/HR | 50.00 GAL/HR |
| M2 | 1.4 GAL/HR | 13.52 GAL/HR |
| M3 | 1.4 GAL/HR | 13.52 GAL/HR |

It was found during the test runs of the scenario that fuel usage by the Blue force was not very significant during the two hours of combat with the two Red regiments. Since the Blue force was defending and moving infrequently, it was consuming little fuel in the two hour period of the combat. So little fuel was used there was no need for fuel resupply to be performed during the combat scenario. For the average fuel use of 20 gallons per tank to cause a need for replacement, the amount of on-board fuel would require an artificially low setting of the fuel tank's 500 gallon capacity. The forward area resupply of fuel was not performed during the production runs of the scenario.

## C. RESUPPLY

### 1. General

Currently an Armor battalion depends upon a fleet of 30 Heavy Expanded Mobility Tactical Trucks (HEMTT) configured to carry fuel or cargo to perform the logistic requirements of the battalion (Figure 3 and Figure 4). The majority of these vehicles are used to provide the hauling capability to supply the four tank companies with logistic

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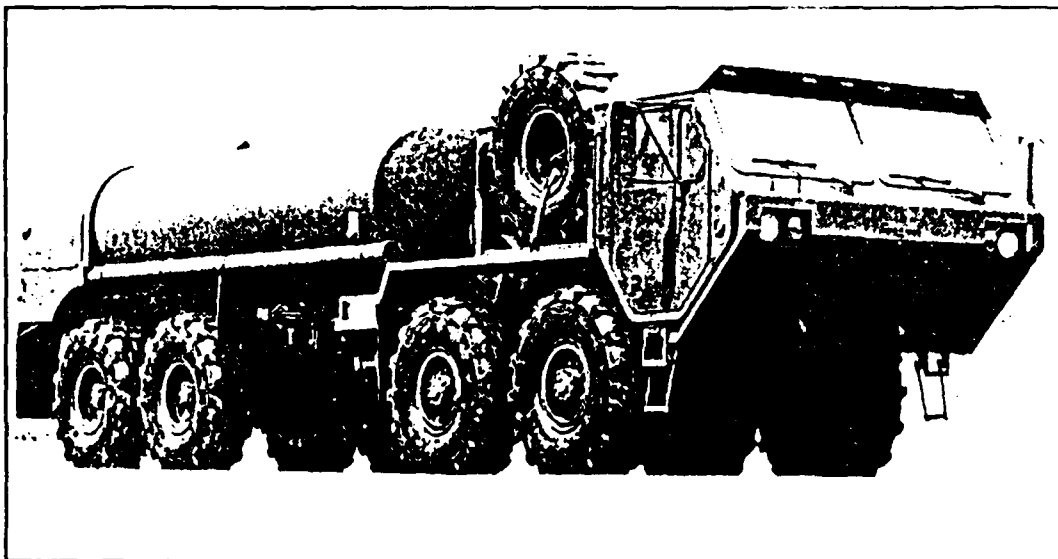
**Figure 3.** Fuel HEMTT



**Figure 4.** Cargo HEMTT

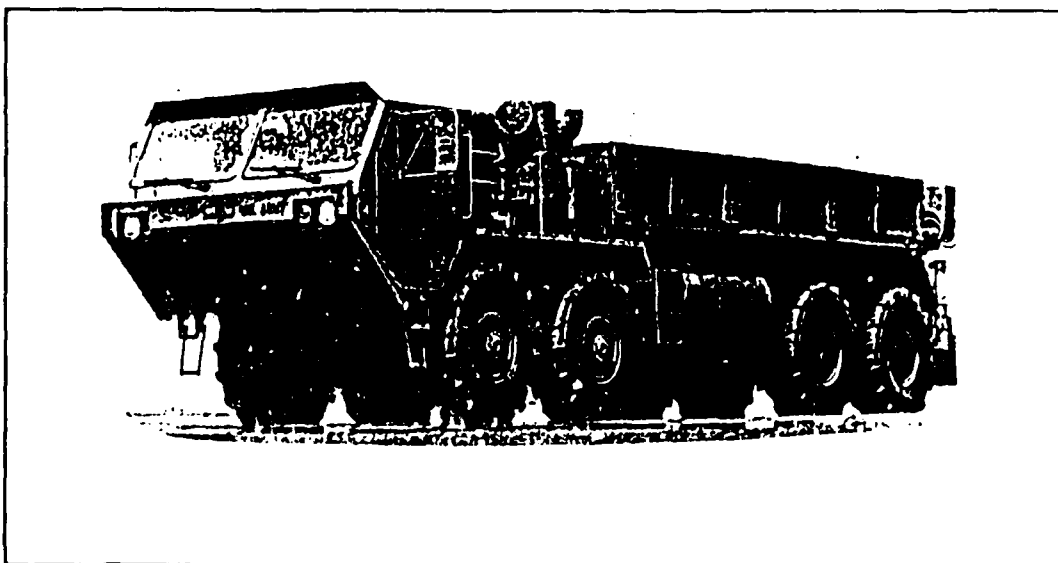support for ammunition and fuel. Current doctrine has the battalion logistic support divided into three areas. Figure 5 shows the location of the different trains locations. These areas are the Battalion Field Trains (BFT), Battalion Combat Trains (BCT), and the Company Trains (CT). These trains areas are located approximately 30, 15, and 1 kilometer respectively, behind the Forward Edge of the Battle Area (FEBA) in a defensive scenario. The needed logistics are brought forward on HEMTTs from the BFT to the BCT as required by the companies to replace expended fuel and ammunition. The HEMTTs will travel as far forward as possible depending upon the tactical situation. During periods of combat the HEMTTs will resupply from positions out of danger from enemy direct fire but may still be subject to intense enemy artillery fire. If the tactical situation permits, the HEMTTs will move to the vehicle fighting positions and resupply from a defilade position near the combat vehicles. One ammunition and one fuel HEMTT per company are currently located at the BCT. These are for emergency resupply to the combat vehicles when the tactical situation does not allow time for the HEMTTs to come from the BFT.

Studies done by the Armor School at Fort Knox and by FMC of San Jose, California show that wheeled soft-skinned logistics vehicles lack the mobility and survivability to perform in the forward combat area. Logistic vehicles will spend considerable time off paved roads and may also be
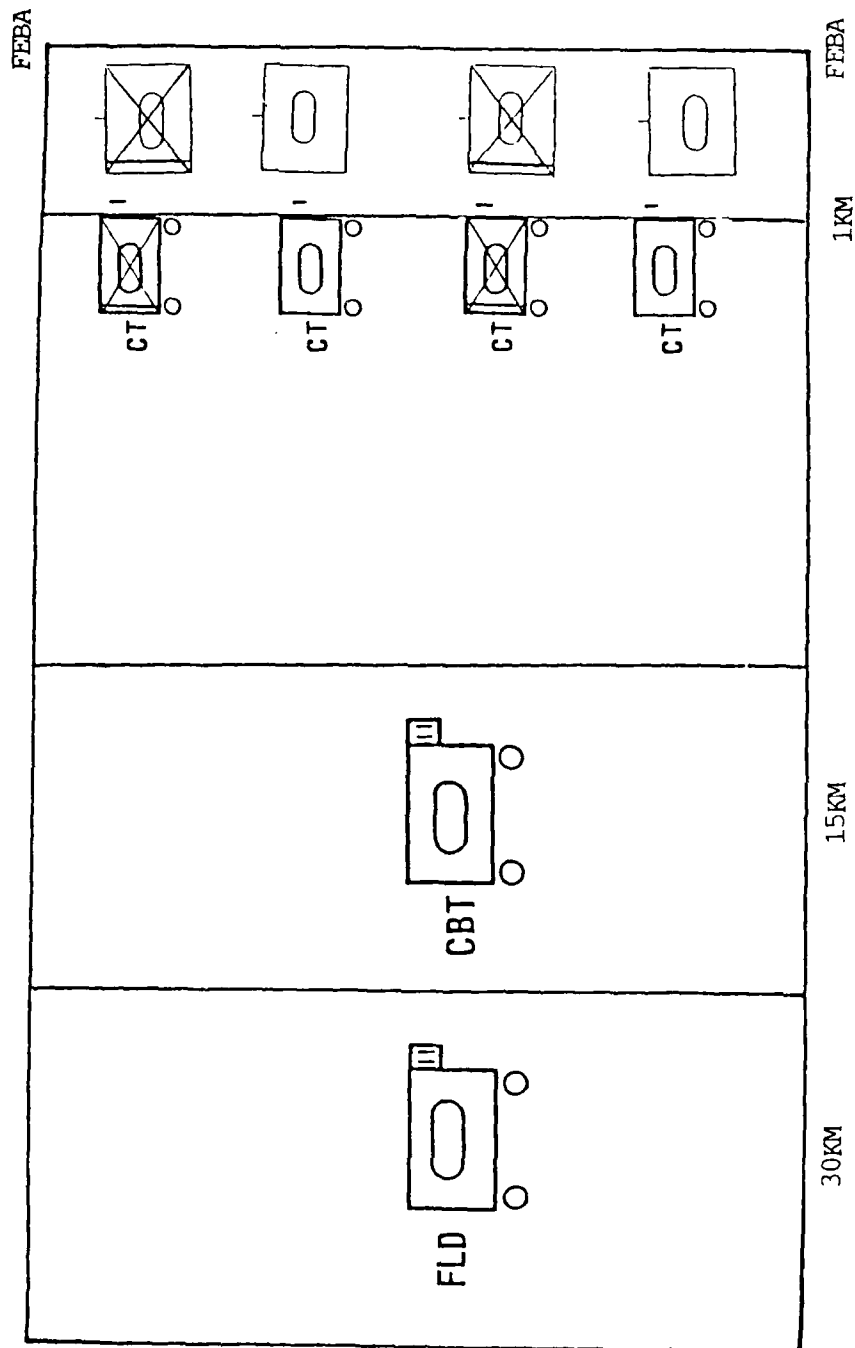
Figure 5.  Trains Locations

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subject to heavy artillery fire in the forward area. To counter these deficiencies it has been suggested that the Army augment the current HEMTT fleet with a tracked vehicle with armored protection for both the crew and cargo. The tracks will provide greater off-road mobility in the forward area matching the mobility of the combat vehicles that it is supporting. Armor will supply the crew and cargo protection against small arms and artillery fire. This tracked and armored resupply vehicle is called an Armored Resupply Multipurpose System (ARMS), Figure 6. The ARMS will be used to provide resupply in the forward combat area. This is the area from the BCT forward to the FEBA. HEMTTs will still be used to transport supplies from the BFT forward to the BCT. At this location the ARMS will be resupplied from the HEMTTs. The ARMS will carry the supplies forward to a position protected from direct fire or during a lull in combat to the fighting position.

## 2. Resupply Vehicle Capabilities

### a. HEMTT

The HEMTT is the primary resupply vehicle found in Armor battalions today. It is configured to carry either fuel or cargo. The HEMTT is a soft-skinned, wheeled vehicle that provides little protection to its crew or cargo from battlefield damage. Its performance is excellent on paved roads and hard-packed trails, and it also performs well moving supplies over long distances.
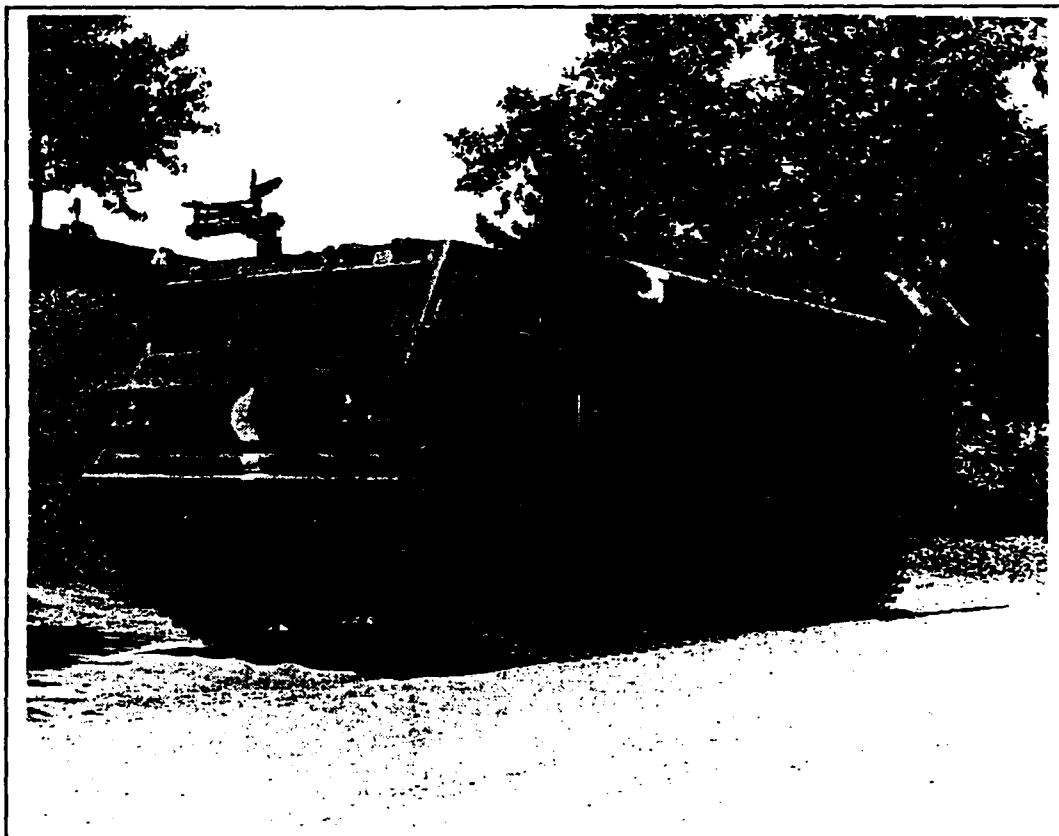
**Figure 6.** ARMS

b.  **ARMS**

The ARMS modeled in this simulation is based upon the armored resupply vehicle designed by the FMC Corporation of San Jose.  This vehicle can be configured to carry either ammunition or fuel.  The cargo carried by this tracked vehicle is protected from artillery fire and small arms fire in an armored cargo bay.  Because it is tracked, the ARMS will perform well during off-road travel.  This will give it mobility that is comparable to the combat vehicles for which

it is providing resupply of ammunition and fuel. The operating characteristics for the HEMTT and ARMS are listed in Table 6.

TABLE 6

HEMTT AND ARMS OPERATING CHARACTERISTICS

| VEHICLE | TANK ROUNDS | TOW MISSILES | 25mm | FUEL |
|---------|-------------|--------------|------|------|
| HEMTT | 240 | 50 | 5000 | 2500 GAL |
| ARMS | 180 | 35 | 5000 | 1800 GAL |

## 3. Resupply Doctrine

Today's Soviet forces field a large, highly modern and mobile force of armored vehicles. This force is trained and organized to conduct a violent, fast-paced, offensive action. The defending force against such an attack must be able to rearm quickly to sustain its combat power. Defending forces no longer have the luxury of displacing far behind the FEBA to rearm. The defending force must be able to rearm quickly, maintaining the maximum amount of combat power as far forward as possible.

Five different resupply options will be used in this thesis to resupply the Blue force with forward area resupply.

- ARMS-1: ARMS from 500 meters behind battle positions

- ARMS-2: ARMS starting from the Battalion Combat Trains

- HEMTT-1: HEMTTs from 1000 meters behind battle positions

- HEMTT-2: HEMTTs starting from the Battalion Combat Trains

- HEMTT-3: HEMTTs starting from the Battalion Field Trains

Two resupply options will use the ARMS as its resupply vehicle and HEMTTs will be used in the other three. The HEMTTs will be positioned at the BFT, BCT, or 1000 meters behind the combat vehicles. The ARMS vehicles will be positioned at the BCT or at a position 500 meters behind the combat vehicles. Each resupply fleet will consist of four resupply vehicles. Two vehicles in each fleet will carry 120mm tank ammunition for the two Armor companies, and two vehicles will carry TOW missiles and 25mm ammunition for the two Infantry companies. When the HEMTTs deploy from the BFT or from the BCT, they will resupply from 1000 meters behind the combat vehicles' fighting positions. This location will provide the HEMTTs with some safety from the intense Soviet artillery that the combat vehicles can be expected to be receiving in their battle positions.

# III. SIMULATION RESULTS

## A. OVERVIEW

The purpose of this thesis, as stated in Chapter I, is to analyze two different resupply vehicles that are deployed using various resupply doctrines. This chapter focuses on the analysis of the simulation output.

The combat and events which take place in this simulation can be analyzed by following a time line as the various events in the battle take place. Each replication is run for a total of 120 minutes. At this time the Blue force had been attrited to ten percent of its starting size, was out of ammunition, or the Red force had bypassed its position with at least a company plus size force. After 45 minutes of simulation the Blue force had attrited the first Red regiment down to one-third of its starting combat vehicle strength, and the Blue force had lost approximately one company of combat vehicles. The status of the first regiment of the Red force and the Blue force after 45 minutes of combat are shown in Tables 7 and 8, respectively.

The first regiment has halted and is waiting for the arrival of the second regiment. There are approximately 3000 to 3500 meters distance between the tree lines of the stopped Red force and the defending Blue force. The stopped first regiment would hold in this position until the arrival of the

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TABLE 7

FIRST REGIMENT VEHICLE STATUS

| VEHICLE | REMAINING | LOSSES |
|---------|-----------|--------|
| FST-2   | 27        | 63     |
| BMP-2   | 9         | 21     |

TABLE 8

BLUE FORCE VEHICLE STATUS

| VEHICLE | REMAINING | LOSSES |
|---------|-----------|--------|
| M1A1    | 21        | 7      |
| M2      | 20        | 6      |

second regiment which was following about 15 kilometers behind. Resupply operations are started by the Blue force at the 45 minute point in the scenario. This represents the Blue commander's understanding that he has stopped the first regiment and there is a time window for resupply to be accomplished before the arrival of the second regiment. Resupply is conducted by resupplying one platoon at a time from each of the four companies. When the resupplied platoon returns to its battle position, another platoon from the company is sent for resupply. As many platoons as possible are resupplied from each company before the arrival of the second regiment. After arrival of the second regiment, vehicles are sent to be resupplied individually as their ammunition supply is depleted to zero. At approximately the 95 minute point the forces of the second regiment begin to

come into TOW missile and tank main gun range. The remaining forces of the first regiment join the attack of the second regiment forces, and the simulation is allowed to run until 120 minutes of simulation has passed. Table 9 shows the status of the Blue force ammunition after the first 45 minutes of battle.

TABLE 9

BLUE FORCE AMMUNITION STATUS

| TYPE | CAPACITY | REMAINING | REQUIRED |
|------|----------|-----------|----------|
| 120MM | 420 | 266 | 154 |
| TOW | 80 | 10 | 70 |

## B. MEASURES OF EFFECTIVENESS (MOES)

Five different MOEs were selected to evaluate the different resupply vehicles and doctrines. The five MOEs are as follows:

- MOE-1: number of Red casualties

- MOE-2: number of Blue casualties

- MOE-3: number of resupply vehicle casualties

- MOE-4: number of Blue vehicles uploaded

- MOE-5: number of rounds uploaded

MOE-1 and MOE-2 measure the number of Red and Blue casualties. By measuring the number of Red casualties, the effectiveness of the resupply fleet delivering ammunition may be monitored. In theory, the greater the efficiency of

resupply, the greater the expected number of Red casualties will be. Also, the greater the efficiency of a resupply fleet, the smaller the expected number of Blue casualties will be. The more ammunition a combat unit has, the better it should be able to survive and the better it can destroy the enemy. MOE-3 measures the ability of the resupply vehicle to survive on the battlefield. The greater the number of resupply vehicles surviving, the better the resupply fleet can perform its mission of resupplying the combat vehicles. MOE-4 and MOE-5 measure how many vehicles and how much ammunition are resupplied by the resupply vehicles. The greater the quantity of ammunition resupplied and the more vehicles resupplied indicate a better resupply system.

## C. COMPARISON BETWEEN RESUPPLY FLEETS

### 1. General

Each of the five MOEs will be analyzed. Particular attention will be paid to the differences between the resupply ability of the HEMTT and the ARMS. Also, the four different doctrines for employing the resupply vehicles will be analyzed using the five listed MOEs.

### 2. Vehicle Type

The resupply capabilities of the two different vehicle types will be analyzed. As mentioned, the ARMS is an armored tracked vehicle and the HEMTT is a soft-skinned, wheeled vehicle. The armor protection of the ARMS, in theory, should

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make it less vulnerable to the Red artillery fire than the HEMTT. MOE-3 measures the number of resupply vehicles destroyed by artillery. The results of the simulation are inconclusive in determining the survivability difference between the two vehicles. The ARMS is destroyed twice during 48 runs when it was used for resupply. The HEMTT is destroyed three times out of 72 runs. This gives the HEMTT a higher survivor rate than the ARMS. If the HEMTT option that delivers ammunition from the BFT is excluded from the data, both the ARMS and the HEMTT using similar doctrine lose two vehicles in 48 runs. The resupplying HEMTTs in the BFT runs are out of artillery range during most of the simulation. Two HEMTTs are in range for 20 minutes of the simulation, and the other two resupplying HEMTTs do not move into artillery range during the simulation. This is a function of the BCT's location 25 kilometers behind the battle positions.

### 3. Resupply Doctrine

The resupply vehicles are employed using four different doctrines. The ARMS resupplies the combat vehicles from a position 500 meters behind the combat vehicles. It is either prepositioned at that location or it arrives there after traveling from the BCT. The HEMTT resupplies from a position 1000 meters behind the combat vehicles. It is prepositioned at that location or it arrives there after traveling from the BCT or the BFT.

Analysis of the results for MOE-1, MOE-2, MOE-4, and MOE-5 shows that the doctrine used by the resupply vehicles is the determining factor for the results of the simulation. Values for the data in MOE-1, and MOE-2 are obtained from the mean of the six separate runs for each of the five resupply options. The values used for MOE-4 and MOE-5 are selected from the single run for each resupply doctrine that most closely match the mean amount of ammunition and number of vehicles uploaded for each doctrine.

MOE-1 is analyzed by viewing the FST-2 losses and BMP-2 losses independently versus simulation time, and then together versus time. Figure 7 shows the that number of Red FST-2 losses depends on the doctrine of the resupply fleet. At 75 minutes, before the arrival of the second regiment, the number of FST-2 losses is approximately equal for the different methods of resupply. The HEMTT fleet from the BFT has the greatest number of FST-2 kills at 90 minutes because all the Blue combat vehicles are still in position until this time. When this option is used, because the distance from the BFT to the resupply point is so great, the Blue vehicles have not departed their battle positions to resupply. This allows the Blue force to kill a greater number of Red vehicles initially using this option as compared with use of other options. By 105 minutes the combat vehicles that have been resupplied by the two ARMS fleets begin to destroy more vehicles than with the other resupply options. From 105
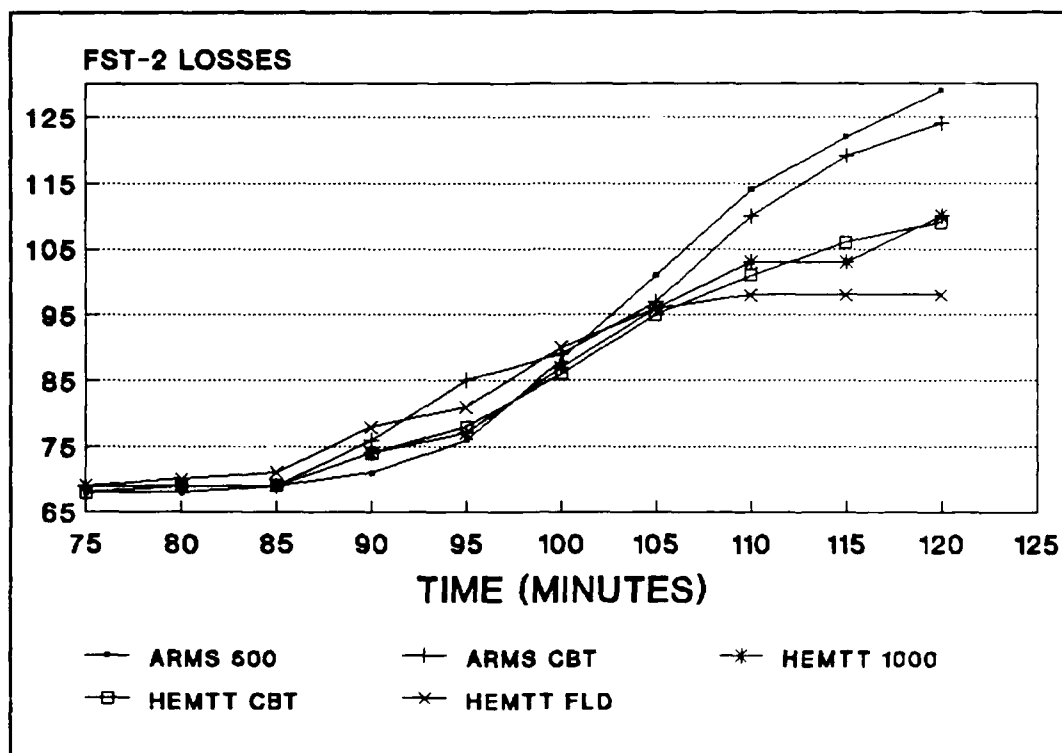
**Figure 7.** Red FST-2 Losses

through 120 minutes the two options using the ARMS for resupply are able to continue engaging the FST-2s, while the other options are out or almost out of ammunition. This is a result of the quick turnaround time from the battle positions to tne resupply vehicles located 500 met ̄s from the battle positions. The ARMS options that loca⸱e resupply vehicles 500 meters from the front are able to provide faster resupply of ammunition to the combat vehicles than the other doctrines.

Figure 8 is a plot of the Red BMP-2 losses versus time. Since the BMP-2 is engaged by the 25mm gun of the
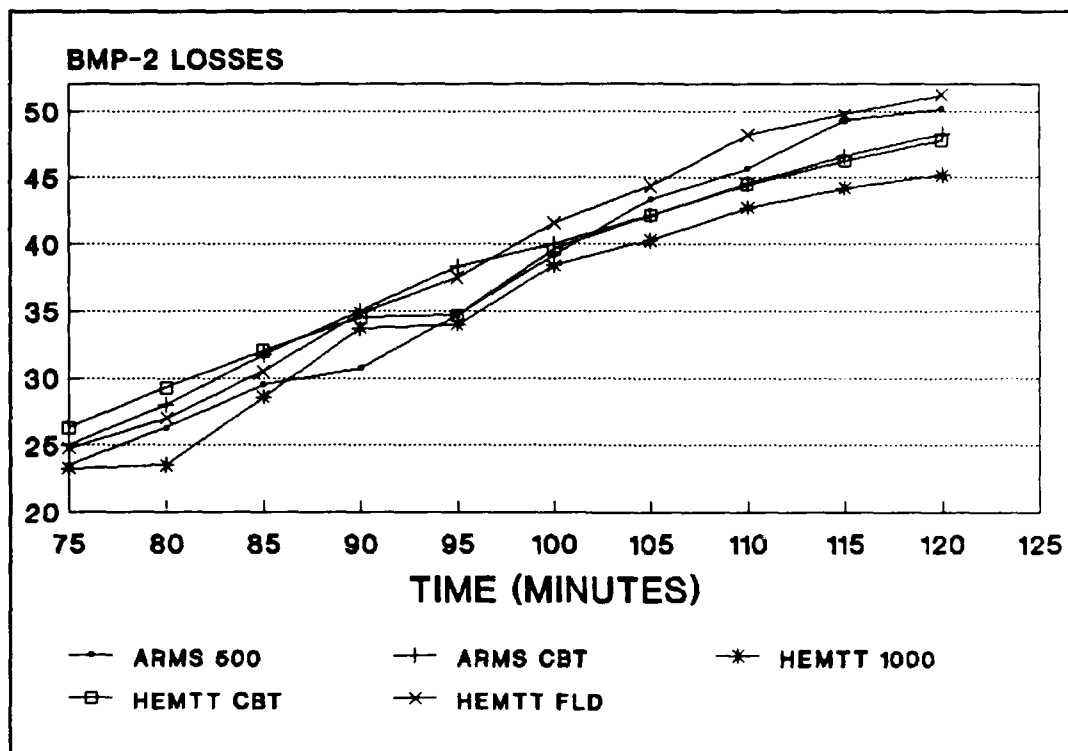
**Figure 8.** Red BMP-2 Losses

Bradley, the losses do not fluctuate greatly. The Bradleys do not deplete their supply of 25mm ammunition, and the engaging of BMP-2s depends upon engagement opportunities. The two resupply options that provide the Blue combat vehicles with the most time in their battle positions kill the most BMP-2s. These are options number one and number five. Option number one, ARMS prepositioned at 500 meters, allows the Bradleys to quickly rearm with TOW missiles and return to their battle positions. These Bradleys are spending little time out of their battle positions and, consequently, have increased opportunities to engage BMP-2s. Option number five,

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HEMTTs from BFT, provides the Bradleys with the opportunities to kill BMP-2s because they are not spending time out of their battle positions resupplying. One HEMTT from the BFT never reaches its assigned company during the 120 minutes of simulation. This allows the Bradleys from this company to engage the BMP-2s for the entire 120 minutes.

The total Red losses of FST-2s and BMP-2s are shown in Figure 9. The results are similar to the results of the FST-2 losses. The two ARMS options provide the best resupply of ammunition. Therefore, when these two options are used, the total Red losses is the highest.

MOE-2 shows the number of Blue vehicle losses related to time. Blue casualties occur as a result of the combat between the two forces and the Blue forces attempts to resupply. The Blue forces have the advantage of being in prepared defilade positions. Movement or firing by a Blue vehicle increases the chance of being detected and fired upon by a Red vehicle. White phosphorous smoke is fired by the Blue artillery in an attempt to screen the Blue vehicles while resupplying. A Blue vehicle that depletes its ammunition can increase its chance of survival by not attempting to resupply.

The number of Blue Abrams losses is shown in Figure 10. The Blue vehicle losses that occur between 45 minutes (when the first regiment stops) and 95 minutes (when the second regiment arrives) occur because the Blue vehicles attempting to resupply are moving out of defilade positions.
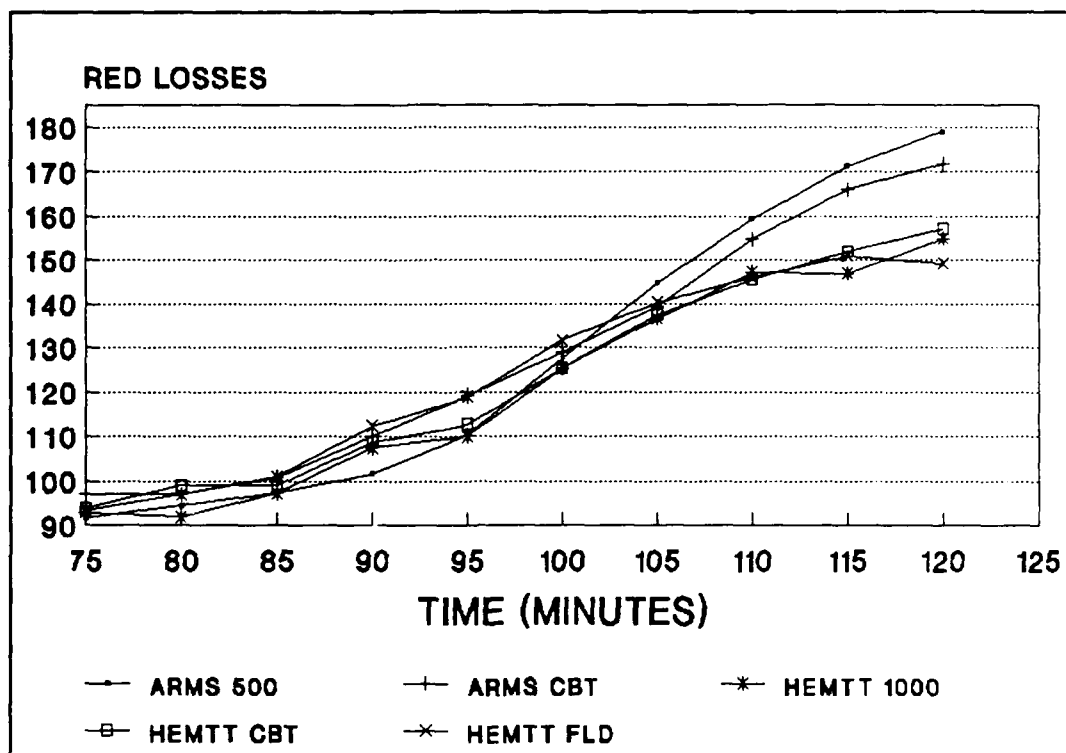
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**Figure 9.** Total Red Losses

This causes the resupply doctrines of ARMS at 500 meters and HEMTTs at 1000 meters to have a greater number of casualties than the other doctrines during this period. Between 95 minutes and 110 minutes (when they are attempting to resupply) the rate of Blue casualties increases for the other resupply doctrines. This is shown by the increase in the slope of the line for Blue losses. After 110 minutes the loss rate increases for the option when the ARMS are located 500 meters behind the combat units. This is a result of having resupplied earlier and therefore depleting ammunition at an earlier point in time than occurs in the other options. The
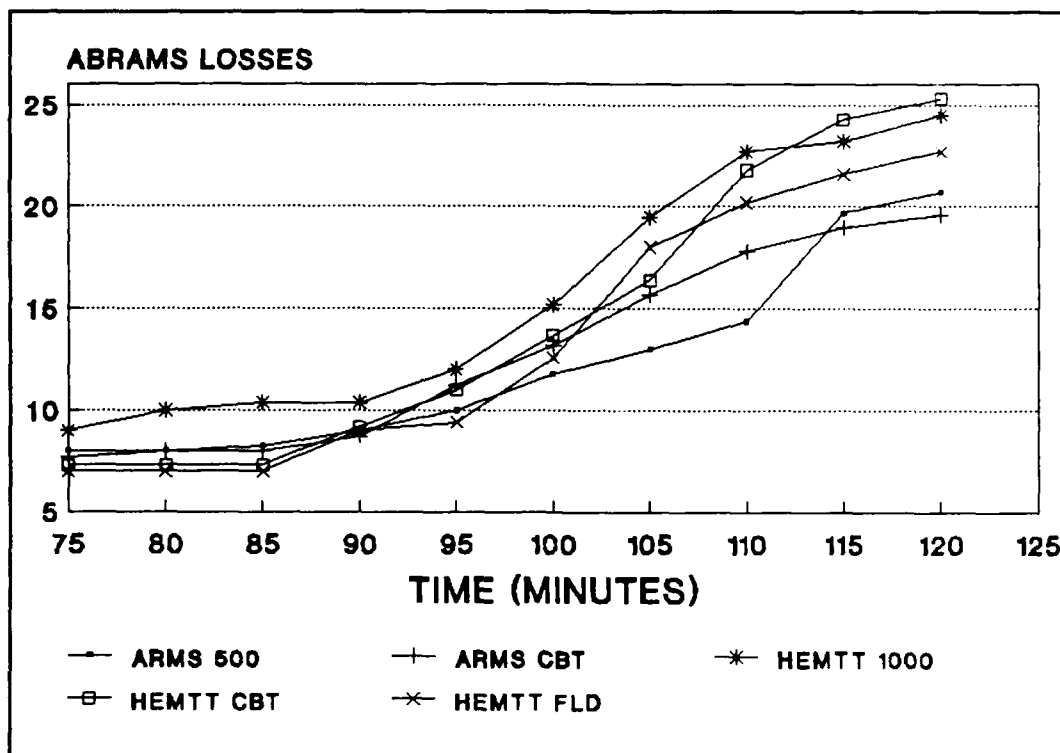
**Figure 10.** Blue Abrams Losses

vehicles using resupply option ARMS-1 are able to perform their initial resupply before the other options, and therefore can attempt resupply again.

The total Blue tank losses is the greatest for HEMTT-1 and HEMTT-2 options. This is a result of the HEMTTs being positioned 1000 meters behind the battle positions. The longer travel time causes the tanks to be engaged by the second regiment as they are returning to their battle positions. HEMTT-3 is the third most effective option for reducing Blue losses, because the Blue tanks do not have the opportunity to resupply and, therefore are not moving out of

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the protection of the battle positions. ARMS-1 and ARMS-2 have the lowest Blue tank losses. The tanks are able to resupply and return to their battle positions before the second regiment arrives because of the short travel distance of 500 meters from the resupply vehicles to the battle positions.

Figure 11 shows the number of Blue Bradleys that were destroyed. The losses vary with time as they resupply using the different resupply options. When the Bradleys have resupplied once with TOW missiles they do not attempt another resupply when this resupply of TOWs is fired. Instead, the Bradleys remain in their battle positions and engage the BMP-2s with their chain guns. As a result the Bradley losses are almost the same for options ARMS-1, ARMS-2, HEMTT-1, and HEMTT-2. HEMTT-3 has the lowest Bradley losses because the Bradleys did not have an opportunity to resupply and, therefore, did not suffer losses while out of their battle positions.

Total Blue losses of Abrams and Bradleys together are shown in Figure 12. HEMTT-1 and HEMTT-2 had the highest number of Blue losses. The longer travel time to the resupply location 1000 meters behind the battle position causes more Blue vehicles using these options to be exposed to the Red direct fire. The remaining three options had similar numbers of Blue losses.
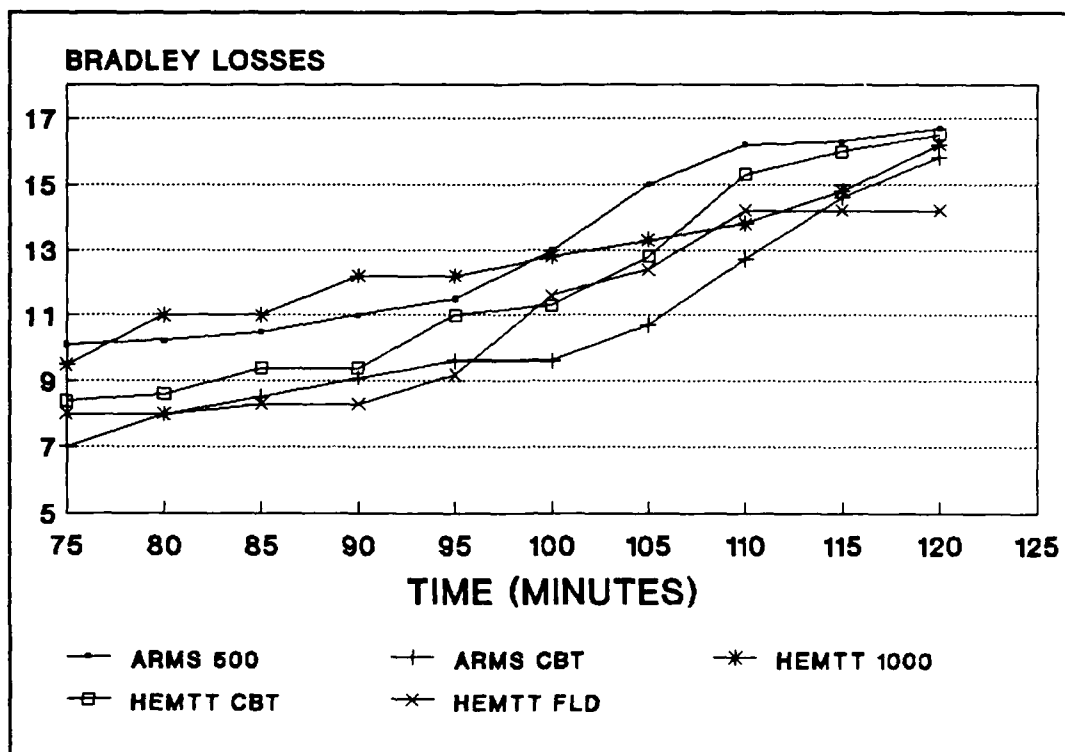
**Figure 11.** Blue Bradley Losses
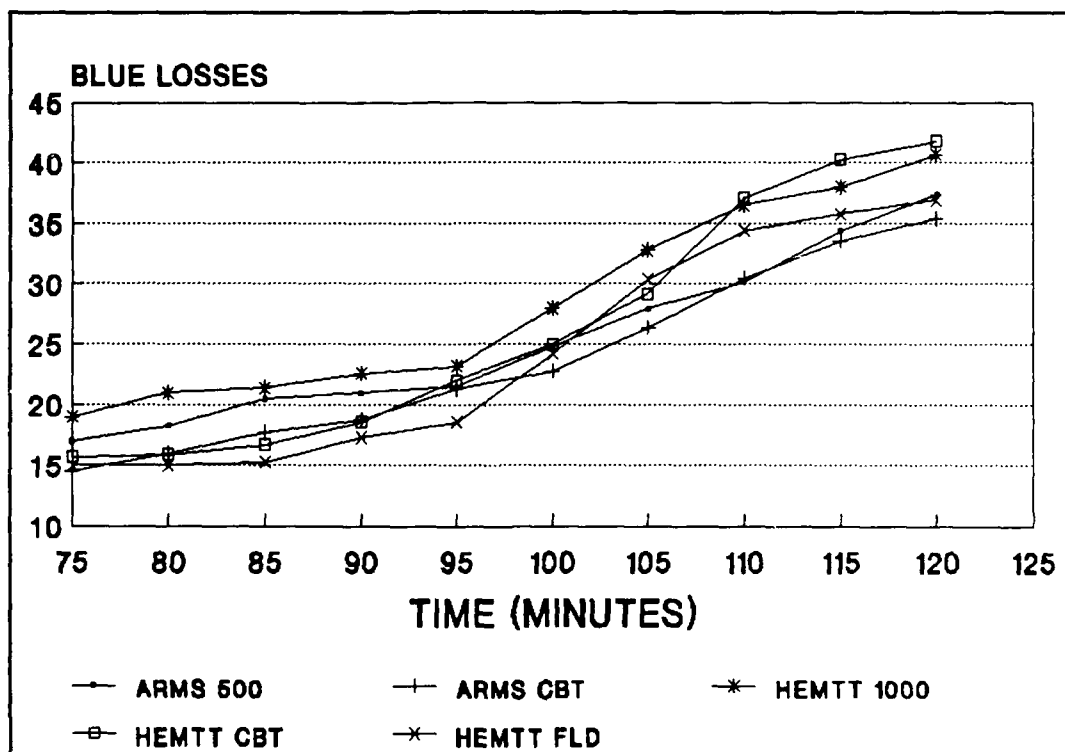
**Figure 12.** Total Blue Losses

MOE-4 shows the number of vehicles that were uploaded using each of the resupply options. A graph of this data is shown in Figure 13. The ARMS-1 option allowed resupply to begin more quickly after the first regiment was stopped and also resupplied the most vehicles. Although HEMTT-1 was third in total number of vehicles uploaded, it was second in speed of resupply. ARMS-2 was able to resupply more vehicles than HEMTT-1 because of the faster turnaround time due to the shorter distance traveled between the battle positions and the resupply location. HEMTT-3 did not upload many vehicles because it was delayed by the 25 kilometer distance from the BFT to the resupply location.

MOE-5 shows that the amount of ammunition uploaded is related to the location of the resupply vehicle. This is shown in Figure 14. ARMS-1 located at 500 meters and HEMTT-1 at 1000 meters are able to provide the quickest resupply because they are the closest to the combat vehicles. Resupply for the ARMS can start at 50 minutes and at 62 minutes for the HEMTTs. The difference in starting times is caused by the longer time it takes the combat vehicles to travel the 1000 meters to the HEMTTs, rather than the 500 meters to the ARMS. The resupply vehicles traveling from the BCT provide resupply later than the vehicles near the front, but sooner than the HEMTTs coming from the BFT. HEMTTs coming from the BCT arrive at the front sooner than the ARMS because of their greater speed on roads. At approximately the 95 minute mark, the ARMS
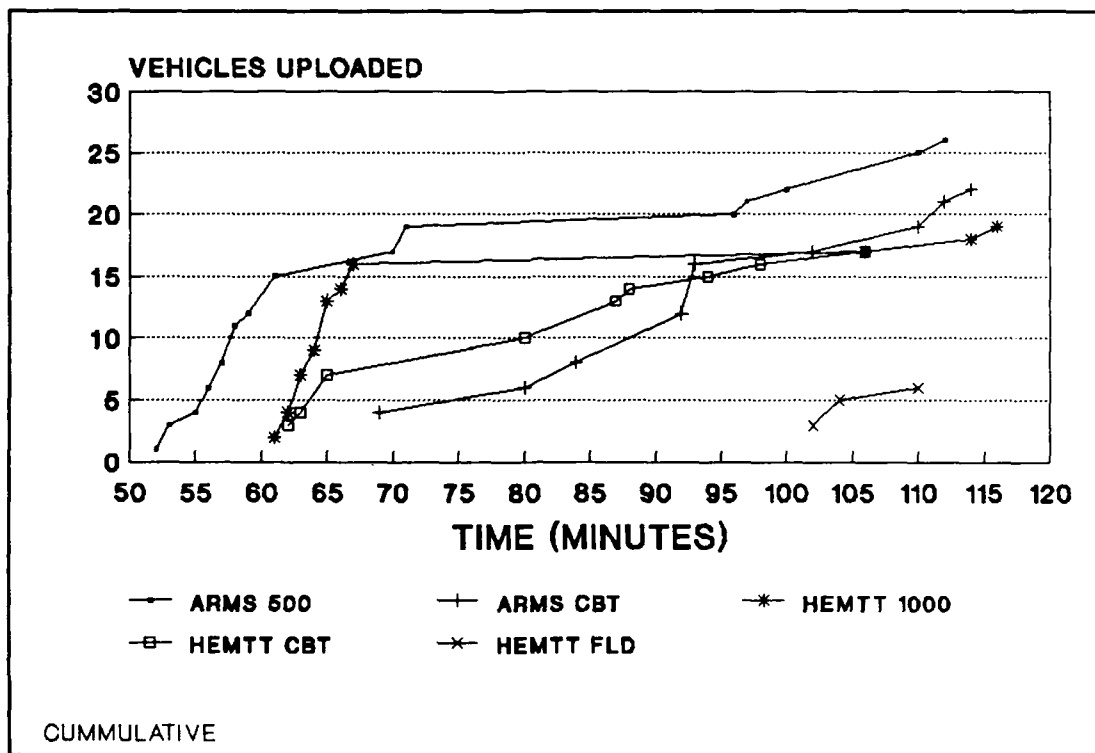
**Figure 13.** Vehicles Uploaded

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AMMO UPLOADED
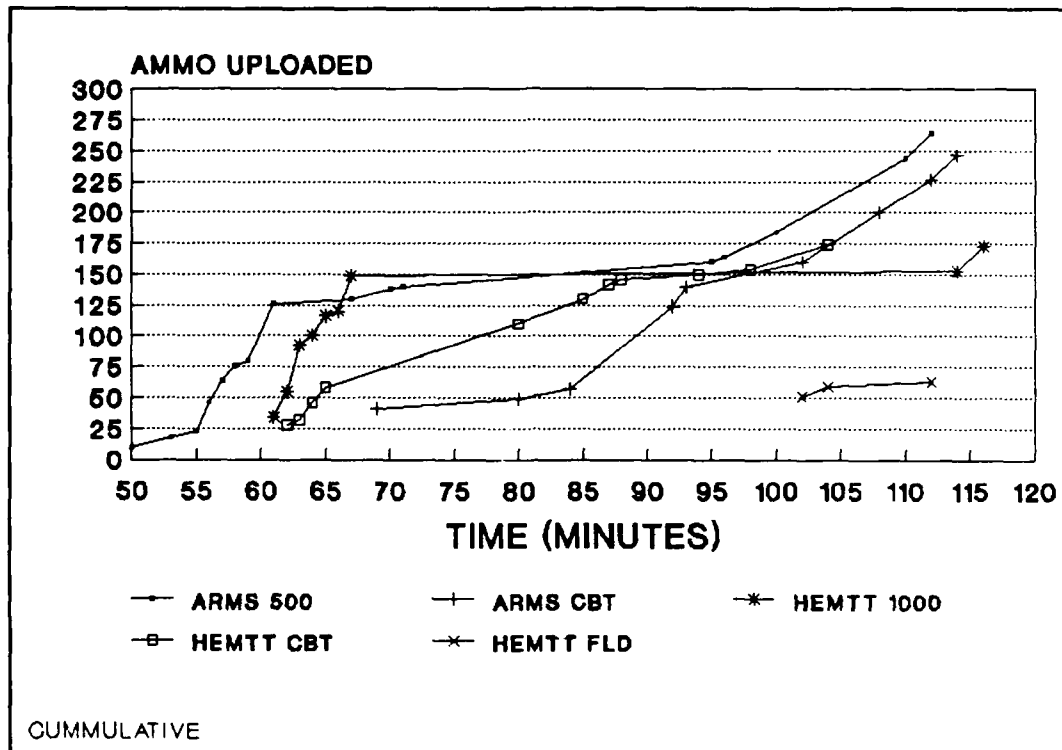
**Figure 14.** Ammunition Uploaded

from the BCT begins to provide more resupply than the HEMTTs from the BCT because they are located closer to the combat vehicles. The HEMTTs that travel the 25 kilometers from the BFT to the front are not able to provide effective resupply to the combat vehicles. Resupply does not begin until 100 minutes of simulation time, and often two of the resupply vehicles do not arrive at the front in time to begin resupply before the simulation ends at 120 minutes.

From the analysis of the different MOEs several conclusions can be made about the resupply doctrines. The resupply vehicle should be placed as close to the combat vehicles as possible while avoiding danger of direct fire from the enemy. This allows resupply to be quickly accomplished and completed before arrival of the second regiment. Smoke is needed to cover vehicle movement from battle positions while conducting resupply operations. Vehicles attempting resupply during contact with the enemy will suffer high rates of attrition.

# IV.  STATISTICAL ANALYSIS

## A.  TWO SAMPLE t-TEST

The Two Sample t-Test will be used to determine whether or not there is a statistical difference between any two population means of the Red tank losses or the Blue total losses for each of the five different resupply options [Ref. 4].  Only the Red tank losses will be analyzed.  The quantity of tank ammunition and number of TOW missiles resupplied will affect the number of Red tanks destroyed.  The Red BMP-2s are killed by the 25mm gun on the M2 or the M3.  This ammunition on the Blue vehicles never reaches a level low enough to reduce the number of BMP-2s killed.

In situations where the combined sample size of the two samples (n,m) is small, (n + m < 30), the Student t-table is preferred for testing the differences between two means over the Normal table.  Three assumptions are made when this test is used.  The populations from which the samples come are normal,  variances of the populations are equal, and the two samples are independent.  Examples of two cases of the two sample t-test with the null hypothesis stating the population means $(\mu_x, \mu_y)$, are equal, and the alternate hypothesis stating the two population means are not equal are given below.

## 1.  Example 1

Let $\bar{X}$ be the sample mean of Red losses from six replications, and $\mu_x$ be the population mean of Red losses from the scenario using the ARMS resupplying from 500 meters behind the combat vehicles.

Let $\bar{Y}$ be the sample mean of Red losses from six replications, and $\mu_y$ be the population mean of Red losses from the scenario using the ARMS starting from the BCT and stopping 500 meters behind the combat vehicles to resupply.

The hypothesis will be tested at a 0.05 level of significance.

$H_0$:  $\mu_x = \mu_y$

$H_1$:  $\mu_x \neq \mu_y$

Let $S^2_x$ and $S^2_y$ be the sums of squares as follows:

$$S^2_x = \sum_{i=0}^{m} (X_i - \bar{X})^2 \qquad S^2_y = \sum_{i=0}^{n} (Y_i - \bar{Y})^2$$

The test statistic T is defined by the following equation:

$$T = \frac{(n + m - 2)^{1/2}(\bar{X} - \bar{Y})}{(1/m + 1/n)^{1/2}(S^2_x + S^2_y)^{1/2}}$$

Because the alternate hypothesis is two-sided, the test procedure is to reject $H_0$ if either $T < c_1$ or $T > c_2$. The constants $c_1$ and $c_2$ are chosen so that when $H_0$ is true, $\Pr(T < c_1) + \Pr(T > c_2) = 0.05$

For this example and the remaining tests of the means of Red losses, the sample size for m and n will be six,

corresponding to the number of replications performed for each resupply option. The value of T in this example is 1.697. Using a table of the t distribution with 10 degrees of freedom, $(m + n - 2)$, $c_1$ and $c_2$ are -2.228 and 2.228, respectively. The value of T is not greater than 2.228 or less than 2.228. Therefore, the null hypothesis that the mean number of Red losses for resupply by the two ARMS options is equal can not be rejected.

## 2. Example 2

Let $\overline{X}$ be the sample mean of Red losses from six replications, and $\mu_x$ be the population mean of Red losses from the scenario using the ARMS resupplying from 500 meters behind the combat vehicles.

Let $\overline{Y}$ be the sample mean of Red losses from six replications, and $\mu_y$ be the population mean of Red losses from the scenario using the HEMTT resupplying from 1000 meters behind the combat vehicles.

The sample size is 6 for both m and n. Testing will still be done at a 0.05 level of significance. Since T is equal to 3.346, and this is greater than 2.228, the null hypothesis is rejected at the 0.05 level. Table 10 summarizes the results of two sample t-tests on the mean of Red tank losses for each of the five different resupply options.

The results in Table 10 confirm the results determined in the analysis of the MOEs. There is a difference between the number of Red tanks that were killed when the ARMS was

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TABLE 10

T-TEST ON THE MEAN OF RED TANK LOSSES

| TEST | MEANS | | T | RESULT |
|---|---|---|---|---|
| ARMS1 & ARMS2 | 128.8 | 123.5 | 1.697 | DO NOT REJECT |
| ARMS1 & HEMTT1 | 128.8 | 109.7 | 3.346 | REJECT |
| ARMS1 & HEMTT2 | 128.8 | 109.3 | 3.795 | REJECT |
| ARMS1 & HEMTT3 | 128.3 | 98.3 | 7.656 | REJECT |
| ARMS2 & HEMTT1 | 123.5 | 109.7 | 2.432 | REJECT |
| ARMS2 & HEMTT2 | 123.5 | 109.3 | 2.780 | REJECT |
| ARMS2 & HEMTT3 | 123.5 | 98.3 | 6.407 | REJECT |
| HEMTT1 & HEMTT2 | 109.7 | 109.3 | 0.0477 | DO NOT REJECT |
| HEMTT1 & HEMTT3 | 109.7 | 98.3 | 0.0972 | DO NOT REJECT |
| HEMTT2 & HEMTT3 | 109.3 | 98.3 | 1.946 | DO NOT REJECT |

providing the resupply and when the HEMTTs were providing the resupply. ARMS was better able to provide resupply to the combat vehicles than the HEMTTs, because it could move closer to the positions of the combat vehicles than could the HEMTTs.

Table 11 summarizes the results of two sample t-tests on the means of the total Blue vehicle losses for each of the five different resupply options.

TABLE 11

T-TEST ON THE MEAN OF BLUE TOTAL LOSSES

| TEST | MEANS | | T | RESULT |
|---|---|---|---|---|
| ARMS1 & ARMS2 | 37.3 | 35.3 | 0.697 | DO NOT REJECT |
| ARMS1 & HEMTT1 | 37.3 | 40.7 | -1.043 | DO NOT REJECT |
| ARMS1 & HEMTT2 | 37.3 | 41.8 | -1.797 | DO NOT REJECT |
| ARMS1 & HEMTT3 | 37.3 | 36.8 | 0.209 | DO NOT REJECT |
| ARMS2 & HEMTT1 | 35.3 | 40.7 | -1.776 | DO NOT REJECT |
| ARMS2 & HEMTT2 | 35.3 | 41.8 | -2.886 | REJECT |
| ARMS2 & HEMTT3 | 35.3 | 36.8 | -0.704 | DO NOT REJECT |
| HEMTT1 & HEMTT2 | 40.7 | 41.8 | -0.439 | DO NOT REJECT |
| HEMTT1 & HEMTT3 | 40.7 | 36.8 | 1.499 | DO NOT REJECT |
| HEMTT2 & HEMTT3 | 41.8 | 36.8 | 3.108 | REJECT |

There is a difference in the mean number of Blue losses in two of the cases. The difference does not appear to be caused as a result of resupply vehicles or the doctrine used for resupplying. In the cases where the t-test rejects, only a difference of one additional vehicle separated the means. This is a statistical difference, but may not be a significant difference on the battlefield.

## B. REGRESSION ANALYSIS

Regression analysis is performed to determine if a relationship exists between the total amount of ammunition uploaded and the number of Red tanks destroyed. Only the Red tank losses were considered because, as mentioned, the Red BMP-2 losses are not caused by one of the ammunitions being resupplied. A plot of ammunition uploaded versus Red tanks killed and the fitted simple linear regression are shown in Figure 15. The fitted line has a positive slope as expected. As the number of uploaded rounds is increased the Blue force has additional ammunition for engaging and killing increasing numbers of Red FST-2s.

Figure 16 shows a plot of the residuals from the regression against the number of uploaded rounds. The residuals are the difference between what is actually observed, and what is predicted by the regression equation. The plot indicates there is not an abnormality which the regression equation has not explained. There is an impression

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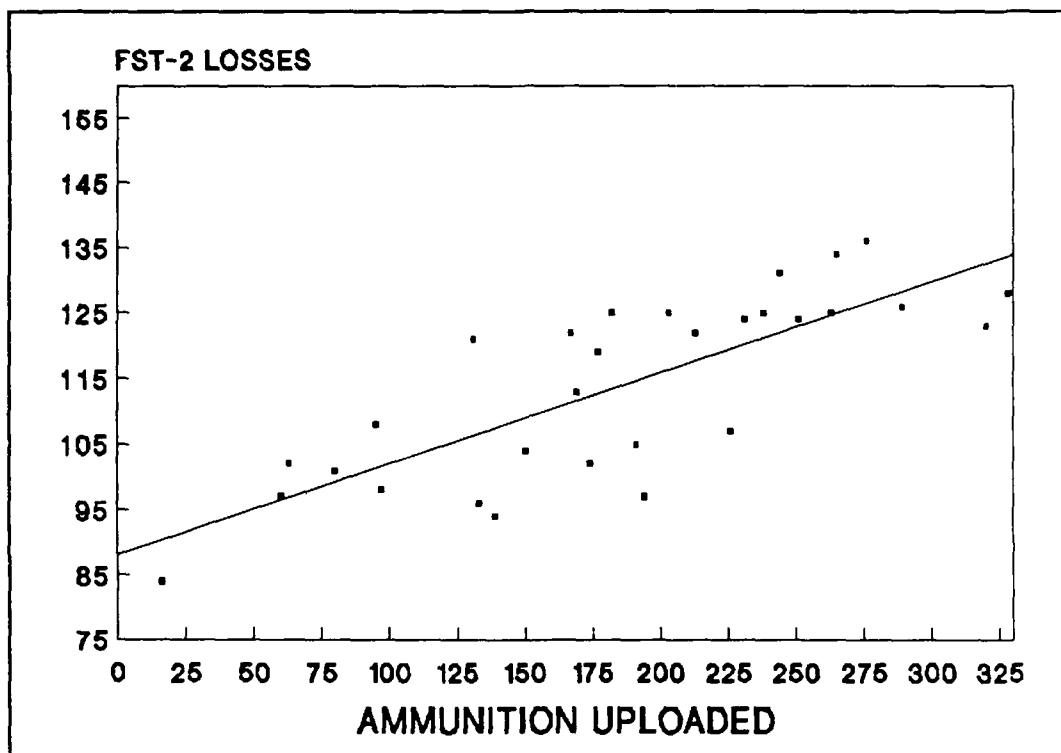
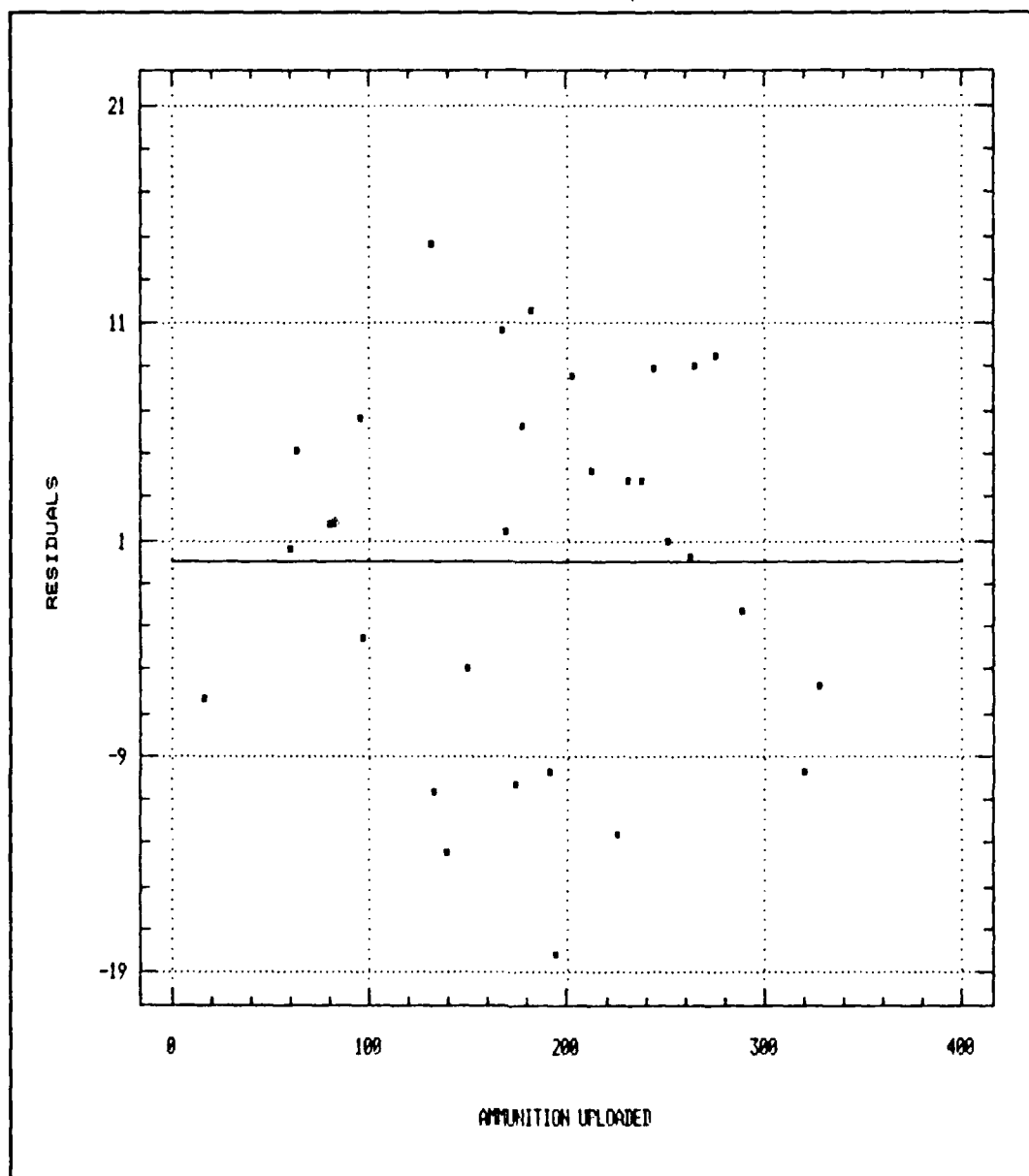**Figure 15.** Regression of FST-2 Losses on
Ammunition Uploaded

**Figure 16.** Plot of Residuals

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of a horizontal "band" of residuals which indicates no unaccounted for abnormality. [Ref. 5]

Each of the six replications from the five different resupply options are used in the regression. Table 12 shows the results of the regression. Since the $R^2$ value is 62.08 percent, it can be said that approximately 62 percent of the variation in the number of Red tanks killed can be accounted for by a linear relationship with the amount of ammunition uploaded.

TABLE 12

REGRESSION RESULTS

| |
|---|
| Equation Y = 88.01 + .14X |
| Correlation Coefficient 0.7879 |
| $R^2$ = 62.08 percent |
| Number of Observations 30 |
| Degrees of Freedom 28 |

# V. CONCLUSIONS AND RECOMMENDED RESEARCH

## A. CONCLUSIONS

This thesis conducts a study of resupply for an armor battalion using the Janus(T) combat model. The scenario is based upon a U.S. armor battalion defending against two Soviet tank regiments. Terrain in the Fulda Gap area of the Federal Republic of Germany is utilized. The Blue force combat vehicles in the model are resupplied with two different resupply vehicles using four different resupply doctrines. Depending upon which resupply option is used, different results occur in the simulation. The Red forces suffer higher casualties when the two ARMS options are used as the resupply doctrines. This is a function of the ARMS being positioned closer to the battle positions of the Blue forces. The combat vehicles are able to resupply and then return to their battle position faster than when the HEMTT resupply options are used. The greater amount of ammunition uploaded allows the Blue force to kill a larger number of Red vehicles. Blue forces suffer less casualties when the two ARMS options and the HEMTT option with the HEMTTs prepositioned at 1000 meters are used. These options allow the Blue force to resupply during the lull in combat that occurs before the second Soviet regiment arrives. This reduces the number of Blue vehicles that are destroyed while attempting to resupply.

The most efficient resupply option for the Army will be one which places the resupply vehicles close to the battle positions. This will allow for resupply to be accomplished quickly and during lulls in combat. The current Army doctrine of resupplying from the Battalion Field Trains clearly does not meet these requirements.

## B. RECOMMENDED RESEARCH

The offensive logistic support of the AirLand Battle Doctrine has not been addressed in this thesis. The heart of the AirLand Battle Doctrine is the Deep Attack. It is during such an operation that the support of a logistic system will be tested to its limits. Offensive action will consume larger amounts of both ammunition and fuel. Resupply for such offensive operations must accompany the combat vehicles. This will require a resupply vehicle that can not only keep up with the combat vehicles, but be able to survive in a more lethal environment.

Janus(T) may be used to model such an offensive operation. The length of simulation time required to stress the fuel resupply option may be prohibitive. Such an offensive scenario may have to be started at a time well into the operation.

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